Usefulness of Pre-Procedure Cavotricuspid Isthmus Imaging by Modified Transthoracic Echocardiography for Predicting Outcome of Isthmus-Dependent Atrial Flutter Ablation

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Background: Anatomic characteristics of the cavotricuspid isthmus (CTI) have been reported to be related to the outcome of atrial flutter ablation therapy. However, preprocedural evaluation of CTI anatomy using modified transthoracic echocardiography to guide atrial flutter ablation has not been well described.

Methods: Transthoracic echocardiography was prospectively performed before atrial flutter ablation in 42 patients with typical CTI-dependent atrial flutter. A modified apical long-axis view was designed to visualize and evaluate anatomic characteristics of the CTI and Eustachian ridge (ER). A prominent ER, extending from the inferior vena cava to the interatrial septum, is defined as an extensive ER.

Results: Twenty-eight patients had straightforward ablation procedures, and 14 patients had difficult ablation procedures. Two patients with difficult procedures had unsuccessful ablation. Multivariate analysis (using CTI length, the presence of a pouch or recess, ER morphology, and significant tricuspid regurgitation as variables) showed that the presence of extensive ER was the only independent predictor of a difficult ablation procedure. The ablation time in patients with extensive ER ($n = 13$) was significantly longer than in those patients with non-extensive ER ($n = 29$) (1,638.4 $\pm$ 1,548.3 vs 413.8 $\pm$ 195.5 sec, $P = .015$). The incidence of difficulty in achieving bidirectional isthmus block was also higher in patients with extensive ER (10 of 13 vs four of 29, $P < .001$).

Conclusion: Preprocedural transthoracic echocardiography using a modified apical long-axis view is useful to characterize the morphology of the CTI and the ER. An extensive ER is a strong predictor for difficult ablation of CTI-dependent atrial flutter. (J Am Soc Echocardiogr 2011;24:1148-55.)

Keywords: Atrial flutter, Catheter ablation, Cavotricuspid isthmus, Eustachian ridge, Transthoracic echocardiography

Radiofrequency (RF) catheter ablation has become the first-line therapy for cavotricuspid isthmus (CTI)–dependent atrial flutter.[1-4] Achievement of bidirectional conduction block across the CTI and the resulting noninducibility of tachycardia after ablation are the goals of this procedure.[1,2,5-8] Although the total success rate of atrial flutter ablation is high, the probability of failed bidirectional block with a conventional catheter is still significant, and the use of a second ablation catheter with a different tip is often needed for successful ablation.[9-13] In addition, a significant incidence of difficult ablation with a requirement for extended procedural time with atrial flutter has been reported.[9,10,14-17] Difficult or prolonged procedures may be associated with increased risk for procedure-related complications. This is particularly true for patients with underlying heart failure, ischemic heart disease, or poor clinical condition. Therefore, the identification of patients at risk for having difficult and prolonged procedures before ablation is important.

The CTI is a region of atrial tissue in the inferior portion of the right atrium that is bounded posterolaterally by the inferior vena cava (IVC) and anteromedially by the annulus of the tricuspid valve. The CTI plays a critical role in the reentrant circuit of CTI-dependent atrial flutter. The Eustachian ridge (ER) is an elevated linear ridge on the CTI that divides the isthmus into the anterior sub-Eustachian portion and the down-slope of the ER leading to the IVC.[18] Imaging studies including angiography, intracardiac echocardiography (ICE), and multiple-detector computed tomography have been used to evaluate the isthmus.[14,17,19-25] Anatomic variability of CTI and ER, demonstrated by right atrial angiography, has been shown to be strongly related to a difficult and prolonged ablation procedure.[17,23,25] In particular, the presence of a long CTI with a pouch confirmed by right atrial angiography and ICE is correlated with the requirement for long duration of RF applications.[14,21,26] In

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Abbreviations
CTI = Cavotricuspid isthmus
ICE = Intracardiac echocardiography
IVC = Inferior vena cava
ER = Eustachian ridge
RF = Radiofrequency
TR = Tricuspid regurgitation

addition, a prominent ER, demonstrated using ICE, has also been reported to be an anatomic barrier to CTI-dependent atrial flutter ablation.[21] However, invasive imaging tools such as ICE and angiography may not be suitable for preprocedural evaluation. Transthoracic echocardiography is a conventional method for the evaluation of the right atrium[27-29] and can be performed noninvasively before RF ablation to anticipate procedural difficulty and to plan appropriately. We have previously reported preliminary data supporting the successful use of transthoracic echocardiography to visualize a long CTI recess in a flutter case before ablation.[30] However, the usefulness of preprocedural transthoracic echocardiography for CTI and ER imaging to predict outcome of CTI-dependent atrial flutter ablation and to identify the patients at risk for prolonged and difficult procedures has not been well described. In this study, we evaluated the feasibility of preprocedural transthoracic echocardiography using a modified apical long-axis view to characterize the morphology of CTI and ER and to correlate morphology with the outcomes of RF catheter ablation for CTI-dependent atrial flutter. We also discuss the role of preprocedural transthoracic echocardiography for identifying patients at risk for prolonged and difficult ablation procedures and to assist in procedure planning.

METHODS

Study Population

This prospective study included 42 consecutive patients (30 men, 12 women; mean age, 62 ± 14 years) who underwent electrophysiologic evaluation and RF catheter ablation for recurrent or refractory symptomatic CTI-dependent atrial flutter. Nineteen patients (45%) had structural heart disease, including coronary artery disease ($n = 11$), hypertensive cardiovascular disease ($n = 3$), valvular heart disease ($n = 1$), dilated nonischemic cardiomyopathy ($n = 3$), and congenital heart disease ($n = 1$). One patient had failed a previous RF ablation procedure for atrial flutter. Three patients had undergone prior cardiac surgery. Informed consent was obtained from each patient. The study protocol was approved by the institutional review board.

Two-Dimensional Transthoracic Echocardiography

Transthoracic echocardiography was prospectively performed 1 day before RF catheter ablation, with images obtained using a 1.6-MHz to 3.2-MHz S3 probe (Sonos 4500; Philips Medical Systems, Bothell, WA). The same experienced sonographer obtained all images from each patient during quiet respiration. The physicians who performed the atrial flutter ablation procedures were blinded to the echocardiographic results.

For image acquisition, the probe was placed initially in the fifth intercostal space at the left midclavicular line. We designed a modified apical long-axis view with a slightly more right-sided adjustment in the orientation of the transducer to visualize the CTI and ER. After a standard apical long-axis view is obtained, the head of the echocardiographic probe is adjusted slightly toward the patient's right side (Figure 1), so that the right atrium, right ventricle, tricuspid valve, and IVC will appear. The IVC is an important anatomic clue. By adjusting transducer orientation from this landmark, the CTI, which extends from the tricuspid valve to the IVC, can be evaluated in more detail.

The echocardiographic imaging parameters, including CTI length, the presence or absence of a pouch or recess, the type of ER morphology, and the presence or absence of significant tricuspid regurgitation (TR) (≥3+), were selected for comparison between patients with normal ablation times and those with prolonged ablation times. The boundaries of the CTI adjacent to the septal leaflet of the tricuspid valve and the IVC are defined as the septal CTI and inferior CTI, respectively. The ER was evaluated in detail from the septal CTI to the inferior CTI region. The heights of the ER at either the septal CTI or the inferior CTI were measured using the electronic calipers incorporated in the ultrasonography software. The length of the CTI was measured at end-systole. CTI length was defined as the distance between the IVC and the tricuspid annulus. The presence or absence of a pouch or recess was carefully evaluated throughout the CTI (Figure 2). A pouch is defined as a broad depression or concavity within the CTI, and a recess is defined as a focal or localized depression within the CTI.[18,25,26] A prominent ER was noted when the amplitude of ER was greater than the average value of all enrolled patients (>9 mm), with the appearance of an elevated membrane outlining the anterior part of IVC orifice. In addition, a CTI with a prominent ER may show a "peak and valley" appearance.[21] On the basis of the ultrasonographic morphology, we defined an extensive ER as a prominent ER extending from the septal CTI to the inferior CTI (Figure 3). Patients were considered to have nonextensive ERs if the echocardiographic morphology demonstrated either a diffusely low amplitude ER or an ER that was only focally prominent (Figure 4). A focally prominent ER was defined if only a focal but not continuously prominent ER could be found.

RF Catheter Ablation

The ablation procedure was performed by more than one attending electrophysiologist, and each performer was blinded to the preablation echocardiographic findings.

A 6-Fr decapolar electrode catheter (Daig Corporation, Minnetonka, MN) was placed in the coronary sinus via the right internal jugular vein. A duodecapolar catheter (Halo; Biosense Webster, Del Mar, CA) was placed along the tricuspid annulus to record electrograms of the right atrial septum and free wall, and a 8-mm-tip ablation catheter (Boston Scientific Corporation, Natick, MA) was used for linear ablation of the isthmus in all patients. Twelve-lead surface electrocardiograms and intracardiac electrographic signals were simultaneously recorded and digitally stored.

A continuous and unmodulated RF current was delivered by a generator (EPT-1000 XP; EP Technology, Boston Scientific Corporation). RF ablation was performed with a linear drag lesion from the tricuspid annulus to the IVC with a preset temperature of 60°C, maximum power of 100 W, and 60-sec preselected pulse duration. The end points of ablation success were defined as complete bidirectional isthmus conduction block and noninducibility of CTI-dependent atrial flutter after ablation.[2,9] The ablation time required to achieve complete isthmus conduction block was recorded in each patient. If complete conduction block could be achieved in 10 min of RF applications, the atrial flutter ablation was considered a straightforward procedure. Procedures requiring >10 min were considered difficult according to the criteria in the previous report.[9,10]